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In the development of the Great Society, both the executive and legislative branches of government seem to have decided that cost effectiveness analysis is definitely "in" as a tool for planning and operational control. The voice of the cost analyst, like that of the turtle, is now heard throughout the land. What this means in an operational sense is that the modern executive now feels completely comfortable only when he has his cost-effectiveness analyst sitting behind and slightly to the right of him when he is called upon to justify his decisions.

For the cost analyst this is heady wine indeed, and it would be easy to give in to the temptation to expand in all directions and set oneself up as an expert on all things from strategy to sanitation.

There are two ideas which have motivated this paper:-- first, that the role of the cost analyst is <u>not</u> to appear after decisions are made and provide some kind of estimate which justifies the decisions; and, secondly, that cost analysis is not an activity which is carried out by itself, but is an important part of a larger analytic activity which is sometimes called systems analysis, sometimes cost-effectiveness analysis, and sometimes cost-utility analysis. This larger activity attempts to examine alternative means of achieving specific goals with the ultimate intention of making the best possible decisions. The main intent of this paper is to show how the cost analyst can usefully participate in this analytic process and provide insights which contribute to the making of the aforementioned "best possible decisions."

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As a vehicle for illustrating what we view to be the role of cost analysis, we shall use simplified examples from a recent RAND study. The particular study selected is one which examines alternative configurations of <u>one</u> weapon system with a particular mission. This type of analysis is equally applicable to comparisons among alternative weapon systems or alternative force postures.

At this point it is worth examining the way in which a cost analyst views such a study. Generally speaking it may be considered as having five major phases, beginning with the formulation and definition of the study, its goals and its framework, and ending with the presentation of the results. The design decisions, to which the cost analyst can contribute significantly, comprise the three middle phases of the study: equipment design, system design, and force structure design. These five phases are depicted and defined in Table 1. It must be noted here that the three design phases do not always occur sequentially. For example, one might begin a study by analyzing possible deficiencies in the force structure of the future, and then proceed to equipment and system design to meet the deficiency.

Let's begin our illustration by assuming that a deficiency is possible in our defense forces in some future year, N, to meet a possible threat from sea-launched ballistic missiles. Without explaining why, let's further assume that we are interested in an airborne patrol defense system as opposed to a land-based defense system. The aircraft in the system would patrol sections of a defense zone extending a given number of miles out from each coastline of the United States. Each aircraft would be equipped with surveillance and tracking radars and defense missiles. Figure 1 illustrates our area defense system and also provides a basis for the logical development of the resource model which we must develop before any cost estimates, and therefore any cost analysis can be made.

This works as follows: on the one hand, the extent of coverage of the defense zone is contingent upon our definition of the probable threat -- more specifically, upon the range of an enemy SLBM (sea-launched ballistic missile). On the other hand, the effective area (or "patrol station") which can be defended by any single aircraft on

Table 1

THE ROLE OF THE COST ANALYST IN A WEAPON SYSTEM STUDY

STUDY PHASES	ACTIVITY	ROLE OF COST ANALYST
I. STUDY DEFINITION	Formulate problem.	Help structure framework of the study.
	Enumerate possible alternative solutions.	Familiarize himself with all aspects of study.
	Prepare context for analysis.	Familiarize other members of study team with current Force and Financial Plan and its implications for the study.
	Recognize limitations.	
II. EQUIPMENT DESIGN	Design and define equipment alternatives.	Measure and present effects on equipment cost of changes in design and performance.
		Continue self-familiarization process.
III. SYSTEM DESIGN	Design and define alternative system configurations and operational modes (peacetime, crisistime, and wartime).	Measure and present effects on system cost of changes in weapon system operations.
		Continue familiarization.
IV. FORCE STRUCTURE DESIGN	Define alternative forces (considering phase-ins, phase-outs, and system interactions as related to most recent Force and Financial Plans).	Measure and present effects on yearly cost of alternative force postures.
		Continue familiarization.
V. PRESENTATION	Devise methods to illuminate study findings, conclusions, and uncertainties.	Present resource analysis consistent with the findings, conclusions, and uncertainties of the study.

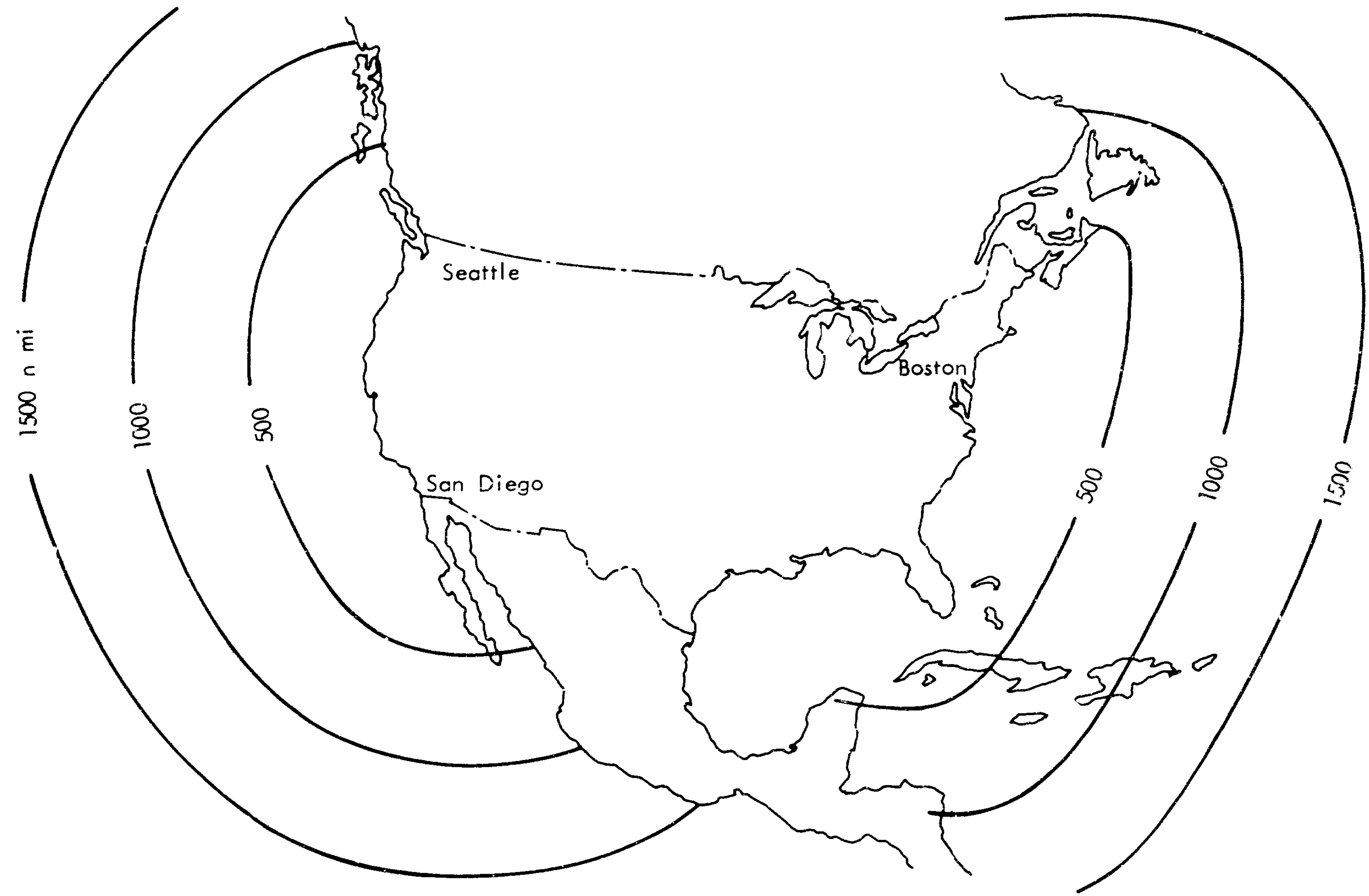

Fig. 1—ASLBM area defense system

patrol depends upon the performance of its defense missiles (range, speed, etc.). These two factors, then -- the extent of the defense zone and the effective radius of action of each patrolling aircraft -- serve as the controlling parameters which determine the requirement for aircraft and missiles on station. Once having determined the number of patrol stations required, we can enlarge our rationale (or actually our model) to include the other resources necessary to turn this concept into a weapon system; namely, backup aircraft and missiles, air bases, trained personnel, ground support equipment, etc.

To get on with our analysis, let's assume that a system has been designed, made up of aircraft and missiles whose performance has been detailed and whose operational concepts have been defined. This system we shall call the "base case" system. Its characteristics are presented in Table 2. Based on these characteristics we can make a preliminary cost estimate for the system, which is presented in Table 2.

Table 2

BASE CASE SYSTEM

Extent of Coverage	500 Nautical Miles Out
Missile Performance	X
Aircraft Endurance	12 Hours
System Fully Operational in	Year N
Operation	Continuous Airborne Patrol
Maintenance Policy	One Shift Per Day (8 Hours)
System Cost (Research and Development; Initial Investment and 5 years of operation)	Approximately $18 billion

Now let's examine this cost in the light of the design and operational decisions that have been made and see how such an examination can contribute to the study as a whole.

First, let's look at the performance of the defense missile and see what significance it has from a resource standpoint. Figure 2 illustrates the relationship between the extent of the defense zone and the number of air stations required, assuming the use of a missile

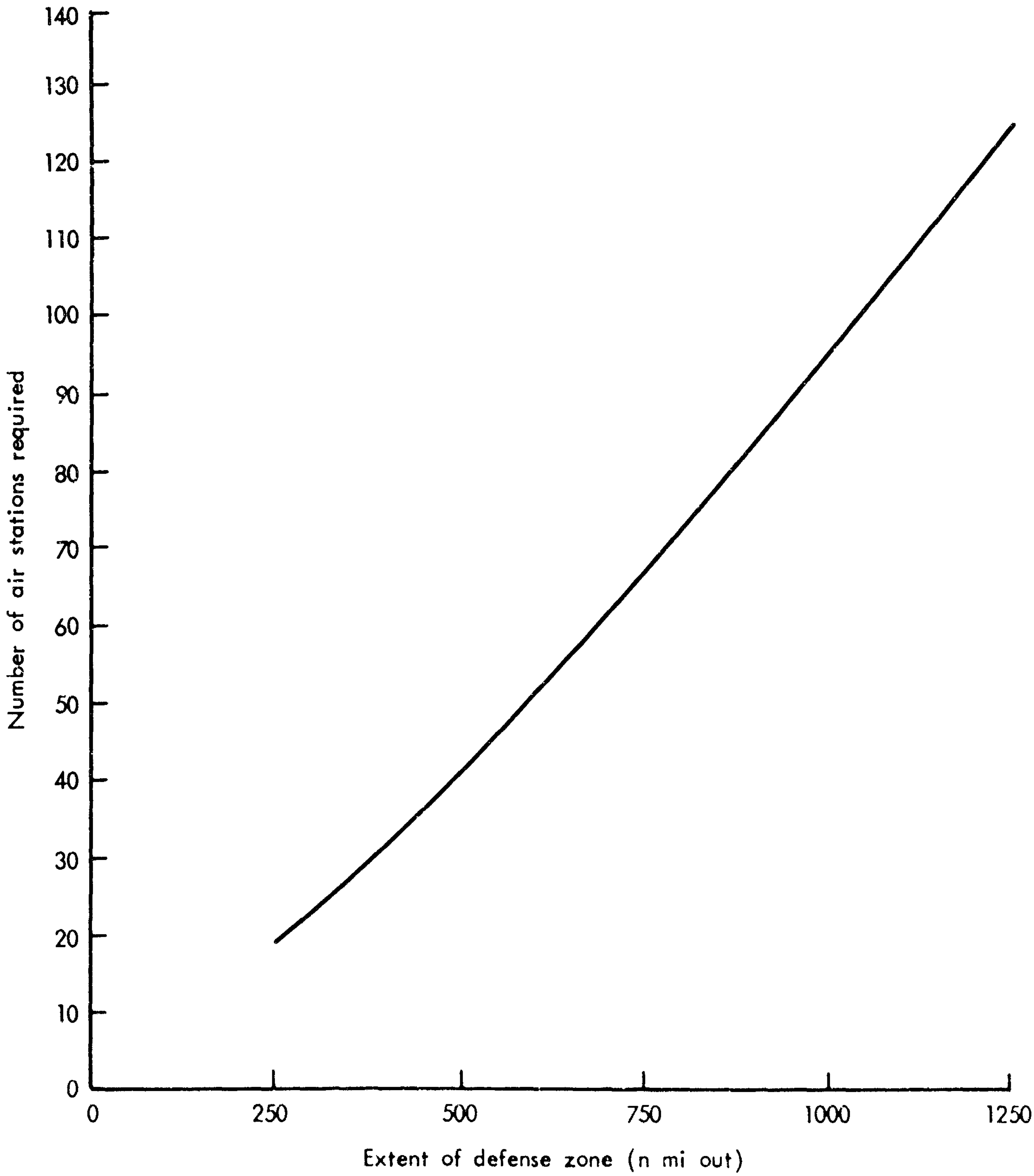

Fig.2—Air station requirements

with capability X. It is easily seen that, for a defense zone extending 500 miles out we would require 40 air stations. This requirement for 40 air stations translates (for the base case system) into a need for resources which can be expressed, in cost terms, as $18 billion (for research and development, initial investment and five years of operation).

All of the foregoing has assumed a missile with capability X. We must recognize that since we are dealing with a future weapon system there exists always the possibility of some technological advancements and we would certainly want to provide some insights as to the possible effects of such advancements. As an example, let's look at the effect of the development and use of a missile with enhanced capability (call it Y) upon our system resource requirements. Figure 3 compares the requirement for air stations for varying defense zones using either missile X or Y. Using the context of the assumptions of the base case, it is evident that the use of missile Y reduces the requirement for air stations from 40 to 27. It may also be noted that the percentage decrease in air stations is greater as the defense zone increases. This might be important in the event that the threat turns out to be greater than anticipated.

It must be realized that the development and procurement of such an enhanced capability missile would cost something, which could then be weighed against the cost advantage of the reduction in air stations.

We can next focus our attention on the aircraft selected to carry the missiles. Here we would hope to provide insights as to the desirable (from a cost standpoint) characteristics of the aircraft. Since this aircraft is assumed to remain on continuous patrol, a key performance factor would appear to be the length of time the aircraft could remain aloft, which we call aircraft endurance.

The aircraft we postulated for the base case system had a maximum endurance of 12 hours. To examine the effect of this assumption on resource requirements we have postulated system configurations using types of aircraft with greater endurance. These aircraft are of an advanced type, having turboprop engines, and are designed primarily for endurance without regard to speed. Figure 4 shows the relationship of

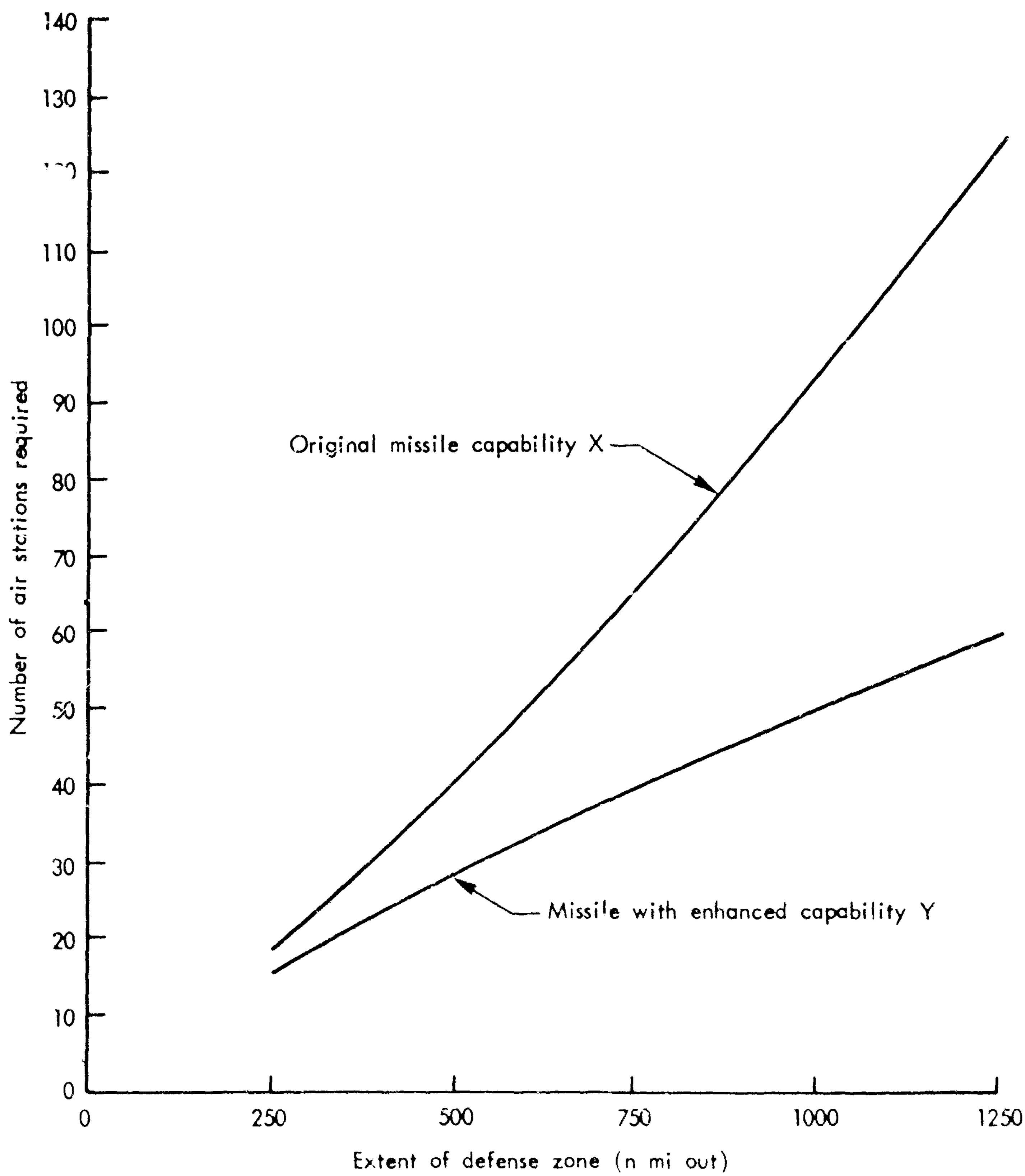

Fig. 3—Air station requirements

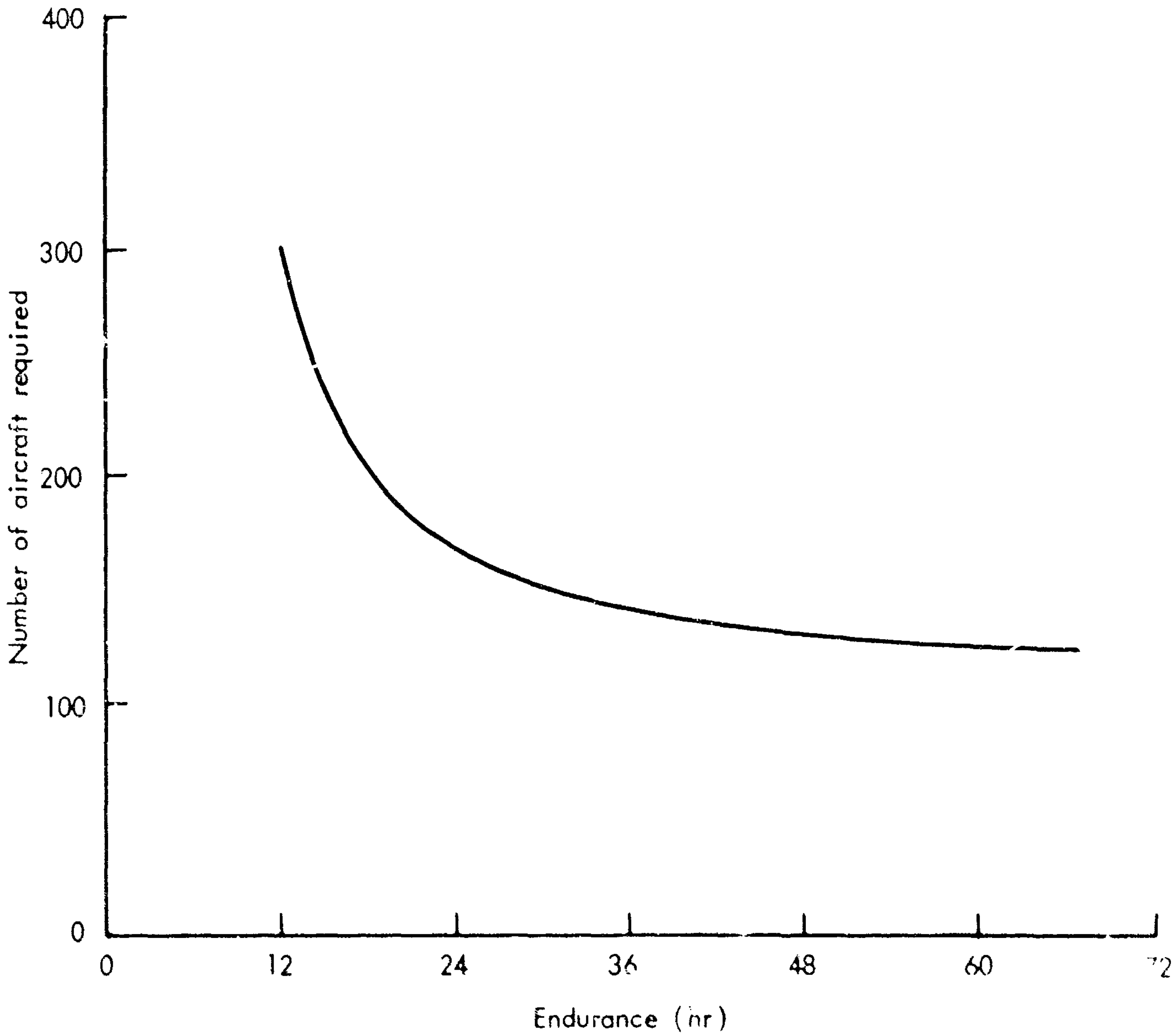

Fig. 4—Number of aircraft required versus endurance

aircraft endurance to number of aircraft required for a system equipped with the advanced missile but having all other characteristics of the base case. It seems clear that with higher endurance there is a lessening of resource requirements, up to approximately 24 hours' endurance, beyond which increased aircraft endurance has a minimal payoff. Here again, one would wish to make the same type of comparison between the cost of the system using the original aircraft with 12 hours' endurance and the cost of the system with the advanced design aircraft with 24 hours' endurance. In essence -- does the saving in number of aircraft required outweigh the development and incremental procurement cost of the advanced aircraft? Here again we are able to take account of the possible uncertainty about our estimate of the threat. In Fig. 5 additional configurations have been added to illustrate the resource significance of aircraft endurance if the required defense zone is greater or less than we presently contemplate. It can be seen that endurance becomes more significant as the defense zone increases. We might then become interested in an aircraft with 36 hours' endurance or more.

The foregoing examples have been selected to show the kinds of contributions the cost analyst could make in the equipment design phase of a study. At the very least this type of analysis can point out some high payoff areas which are worthy of further investigation by the equipment designers. It goes without saying that in order to make such contributions the cost analyst must be a participant at the beginning of the study.

Now let's talk about how we plan to operate the system, and the cost significance of the assumptions we make about system operation. In examining an aircraft system, or any other system, for that matter, one is tempted to dwell upon the tactical aspects -- the flying, the mission, and other interesting aspects of the activity -- forgetting that, as with an iceberg, the significant aspects may not be immediately visible There is, however, no way of getting around the fact that a significant part of the cycle time of any aircraft is devoted to non-mission activities. It would appear well worth while to examine these non-flying parts of the aircraft cycle to determine if

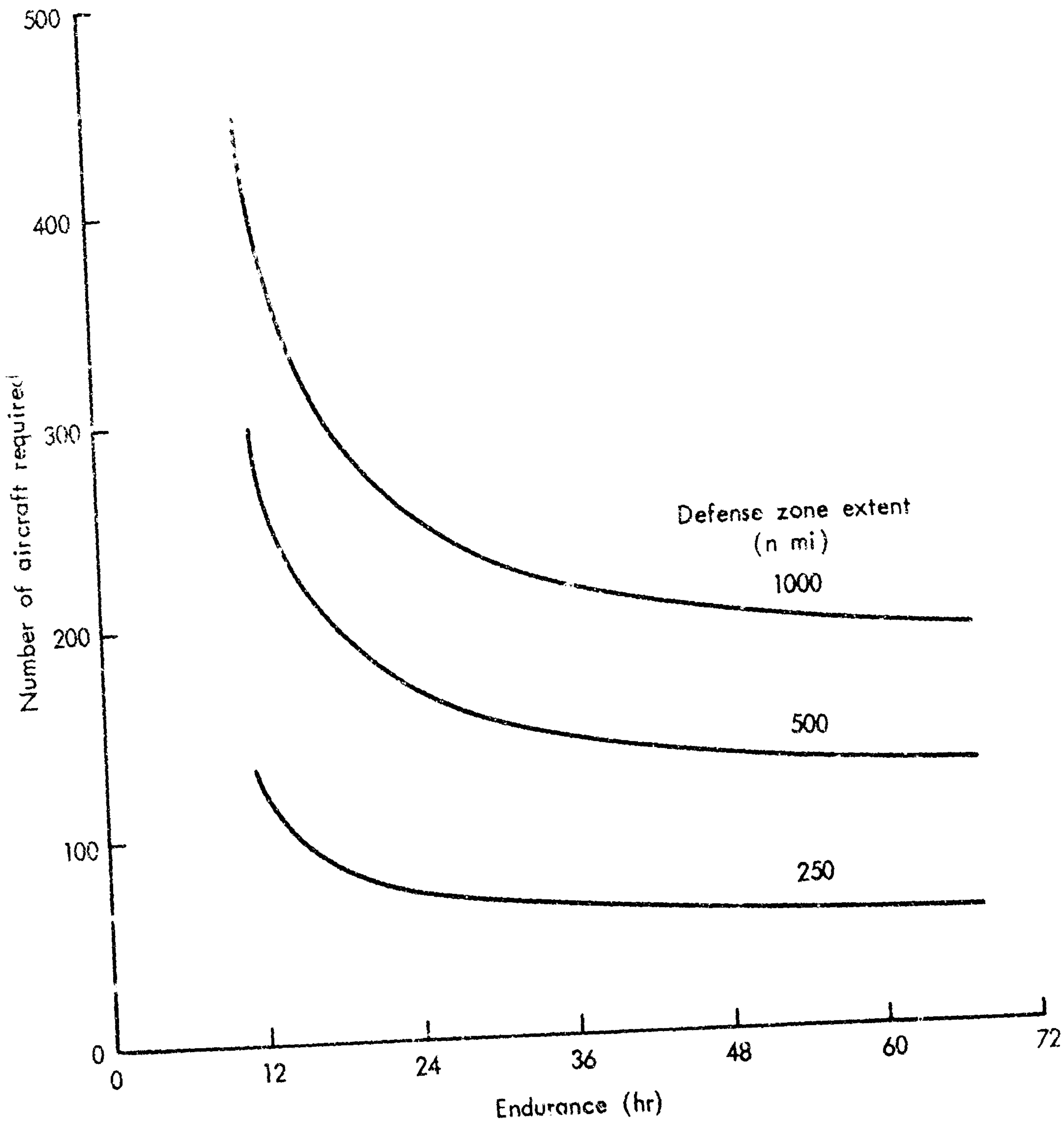

Fig.5—Number of aircraft required versus endurance
(varying defense zones)

the assumptions made about them have any great cost significance. Figure 6 depicts what we envision as the aircraft cycle for the mission we are examining.

To illustrate what we mean by cost significance in this area, let's focus upon one aspect of the ground activities. In the base case we assumed a one-shift maintenance policy, which means that trained personnel would be available to inspect and repair the aircraft and missiles for an eight-hour period each day, seven days a week. This also means that aircraft requiring maintenance during the remainder of each 24-hour day would be obliged to await the following day's shift. Since we have already noted the important effect of aircraft endurance upon the resource requirements, and since it would appear reasonable to assume that the frequency with which an aircraft is forced to return to base could be related to its maintenance requirements, let's start by again looking at the relationship (already presented in Fig. 4) between endurance and number of aircraft required, given the single-shift maintenance policy. (For convenience the relationship is repeated in Fig. 7.)

What if we decrease the wait for maintenance by increasing the number of shifts to two or three? Figure 8 shows how this would substantially lessen the requirement for aircraft, especially if the aircraft have short endurance. We could then proceed to compare the additional cost, in terms of personnel, with the cost savings in terms of aircraft.

By putting together such analyses as the foregoing, and others which we haven't mentioned, we are at last able to look at an extremely cost-significant aspect of our system: the actual use we can get out of our aircraft. This is a most important point precisely because the cost of the aircraft is a major part of our total system cost, and the use we can make of each aircraft will determine how many we must buy. The rate of aircraft utilization, as we view it, depends upon many policy decisions (similar to that made about maintenance policy). These policies are capable of being changed if necessary, and it is incumbent upon the cost analyst to point out cost significant possibilities in this area too.

AIRCRAFT CYCLE TIME

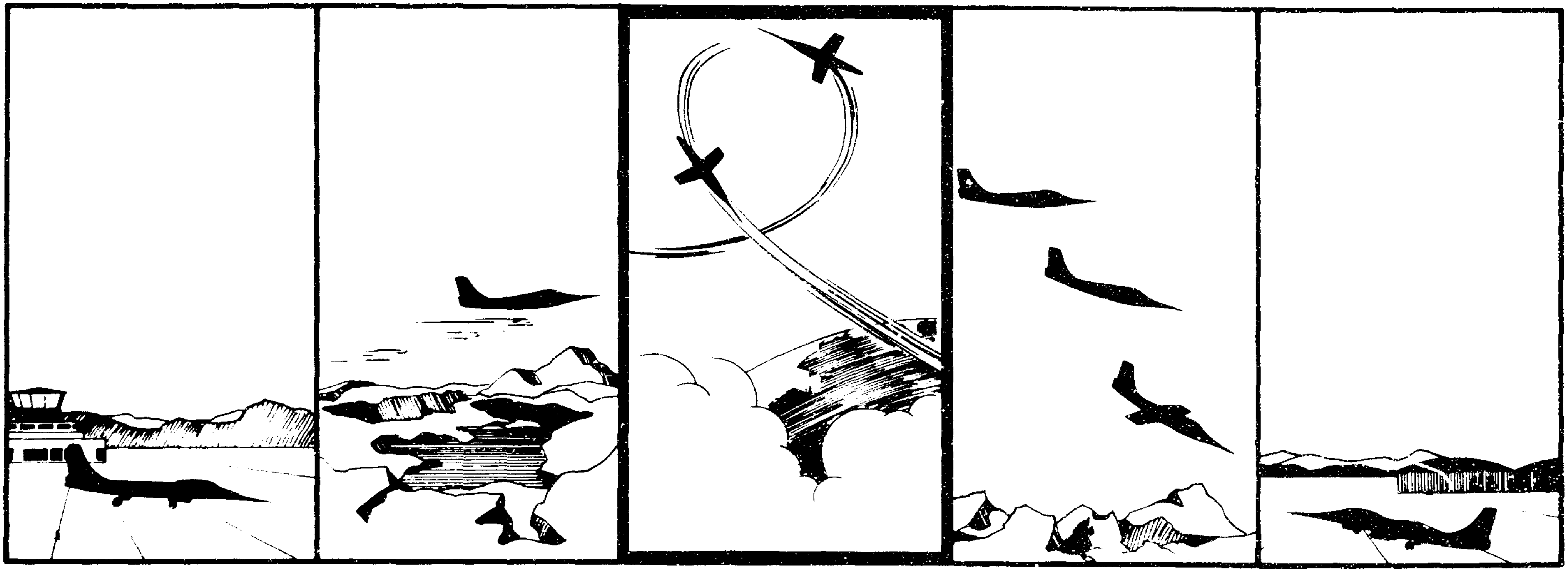

Fig. 6

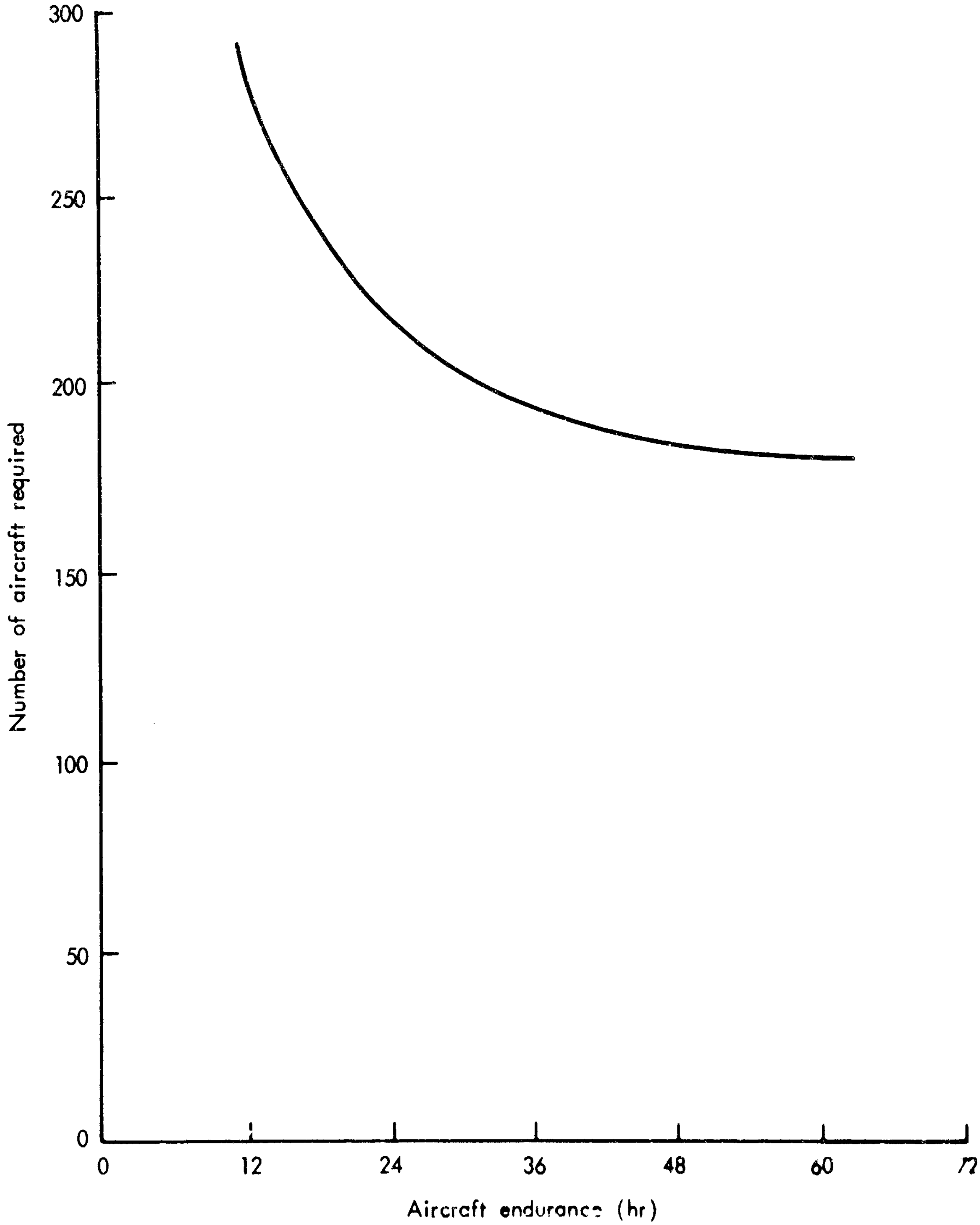

Fig. 7—Aircraft required versus endurance
(one-shift maintenance)

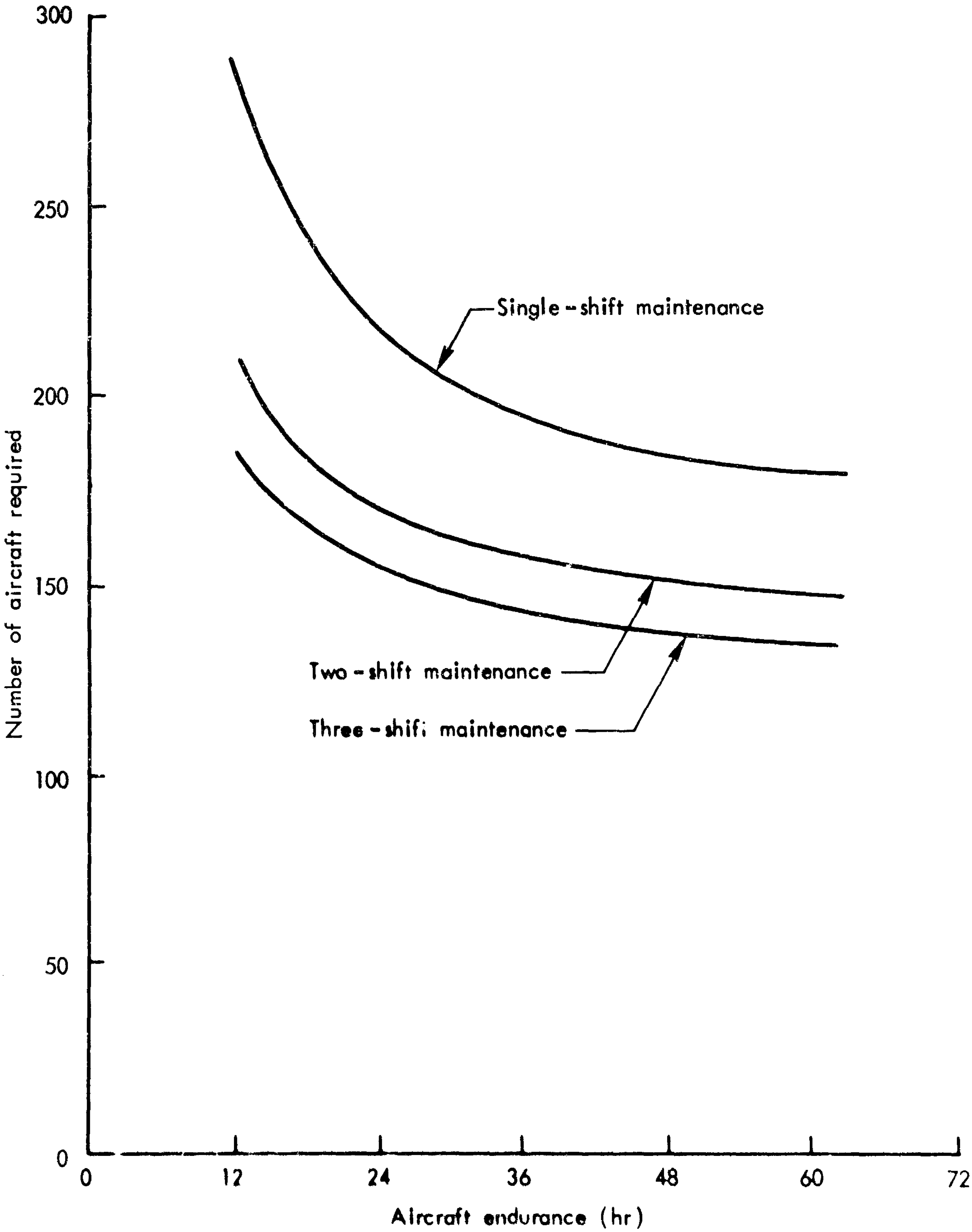

Fig. 8—Aircraft required versus endurance
(varying maintenance policies)

How the system costs are affected by the rate of aircraft utilization is illustrated in Fig. 9. Note how a 10 percent increase in the rate of utilization from 40 to 50 percent decreases system costs by approximately 15 percent.

To examine a different comparison, let us envision the possibility that when this system will be operational there will be adequate warning of an enemy SLBM attack. This implies that we could perhaps operate the system in a different manner by keeping our aircraft on the ground instead of in the air. They could be on 15-minute alert ready to fly out and patrol their stations in the event of a crisis.

On the face of it we would expect that a system with aircraft mostly on ground alert would be considerably less costly than one with aircraft on continuous patrol. Figure 10 provides a comparison of these costs. If the system had 50 percent aircraft utilization, it would appear to be approximately 25 percent cheaper to operate it in a ground alert mode than on continuous airborne patrol. It is most interesting, however, to note that approximately the same cost savings could be realized for either system by increasing aircraft utilization by about 20 percent.

There are, of course, many other possible modes of operation for such a system, and it is not necessary for the cost analyst to provide costs for all possibilities. He can, however, provide some general insights by pointing out the effect on costs of variation in some of the most cost-significant areas.

The final area in which this type of analytic process could contribute is the area of force structure design. This is essentially the point at which the decisions must be made as to when and how the weapons capability already discussed will be introduced into the total force. From an analytical standpoint this involves a series of steps which take the weapon system concepts and place them in a total force framework. For our purposes, this would occur more or less in the following fashion:

1. We establish for purposes of analysis and comparison a "base-case" force, which for our illustration would be the (Continental Defense Forces) portion of Program I of the DOD Force and Financial Pro-

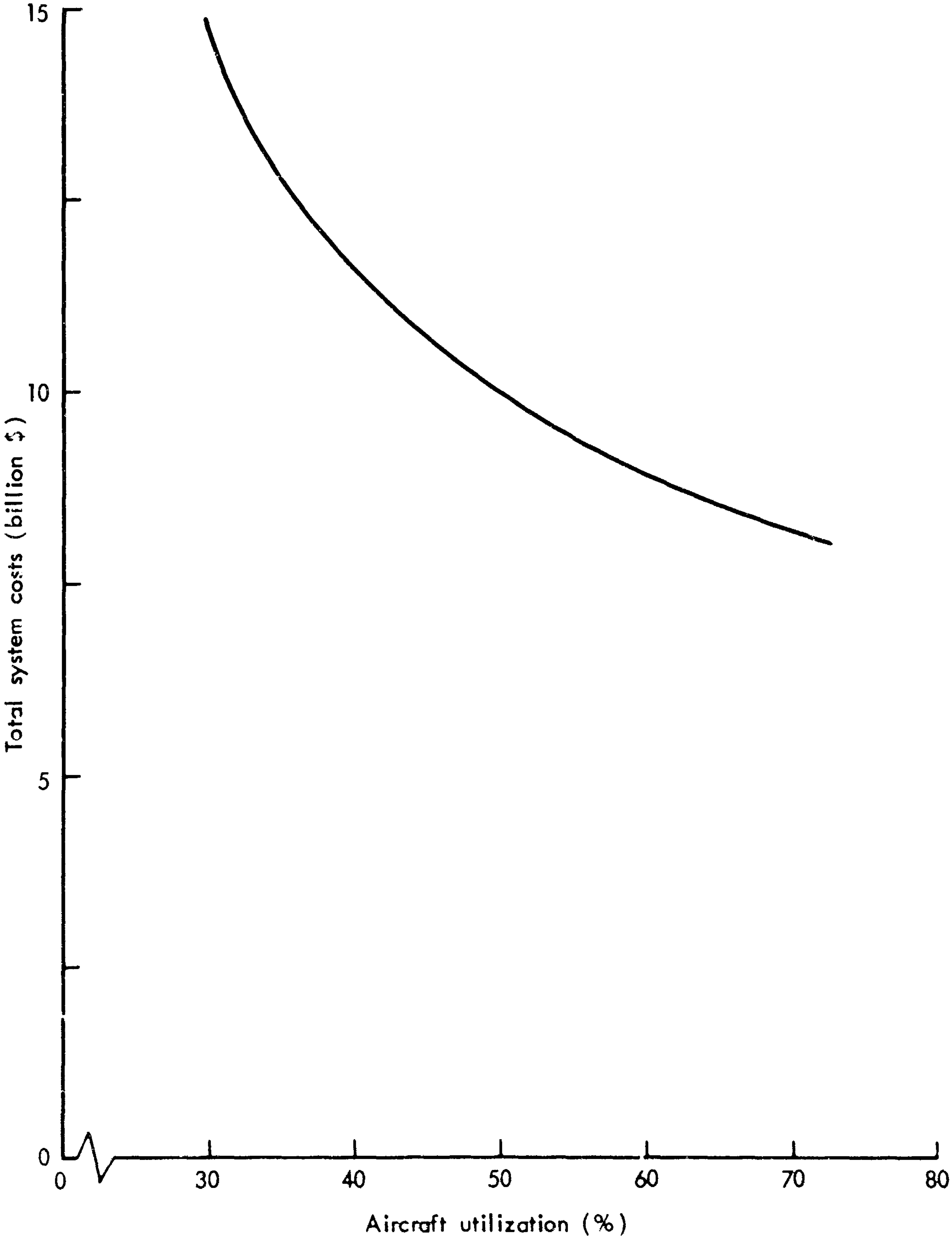

Fig.9—Cost versus percent of utilization

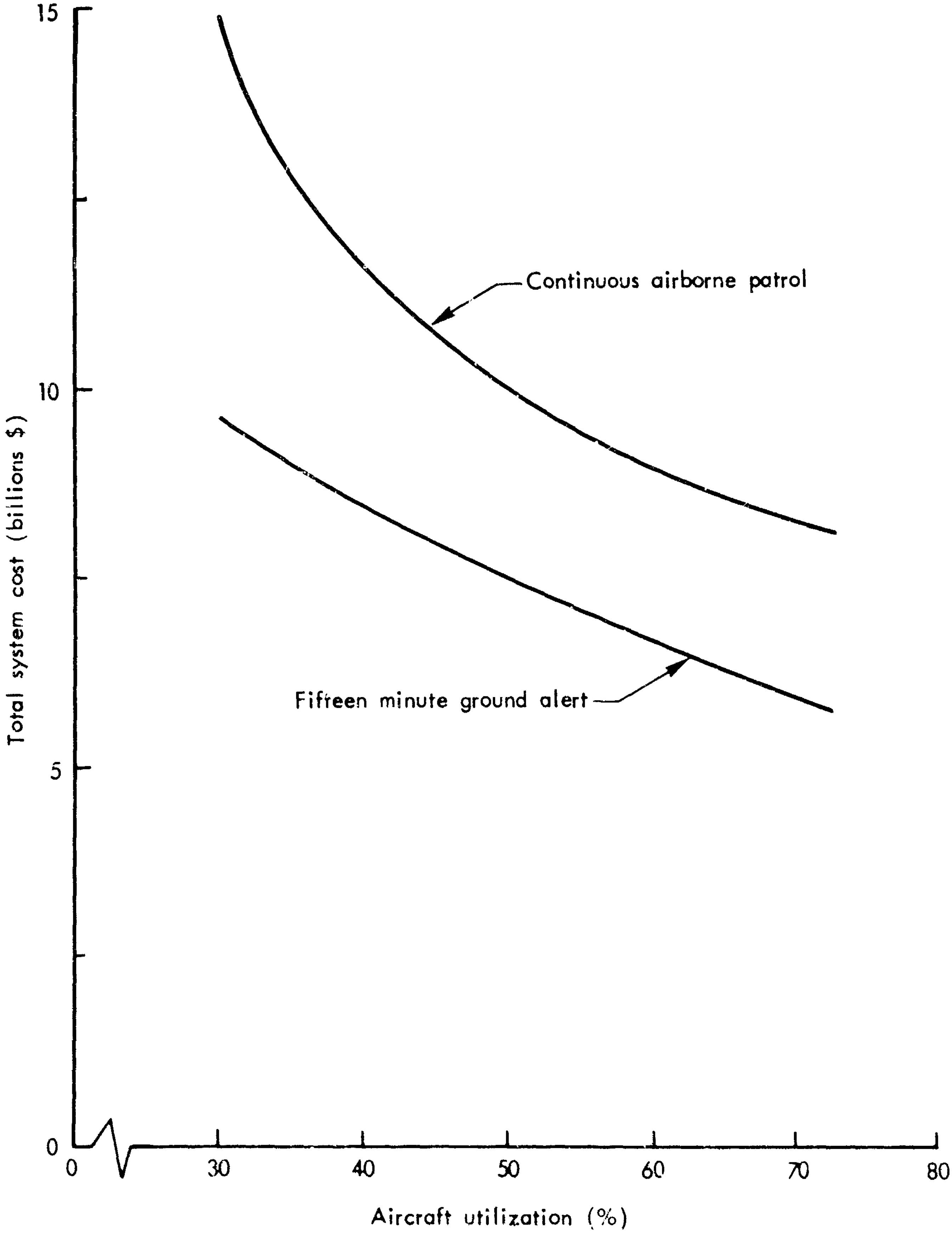

Fig. 10—Cost versus percent of utilization

gram. This base-case force and the resulting costs would be extrapolated from the budget year for as many years in the future as required by the analysis to furnish a proper context within which to view the new capability. We then estimate the cost of this program on a year-by-year basis.

2. We add to the base case force the ASLBM system, and estimate the cost of the new force structure, which includes the ASLBM system, over the same time period. Figure 11 illustrates the cost estimate, expressed in Total Obligational Authority, for the base case force and the new force which we may call Variation 1.

3. We may also wish to examine the year-by-year cost impact of such things as: a) phasing out some portion of the existing force, or b) changing the force size of the proposed ASLBM weapon system, or c) rescheduling either its introduction into the force or the phase-in sequence. One reason to carry out such examinations could be our uncertainty about the nature of the threat or of the probable state of the art in the future time period we have been discussing. Figure 12 shows again the base-case force and Variation 1 projections and, in addition, projections of two additional variations. These variations (2 and 3) show the effect on the force costs of a compressed development and procurement program (Variation 2) and also of a stretched-out program wherein the system would be phased into the force in four equal stages from Year N through Year (N+3) (Variation 3).

In this comparison we can see that although in all three force variations the system cost of the ASLBM system is reasonably comparable, nonetheless changes in the phase-in sequence have serious consequences in terms of the funds that would have to be obligated in specific years. Although this may not have any significance from a cost-effectiveness standpoint, it can nonetheless be a crucial consideration for someone who is obliged to make force structure decisions.

The authors hope that the foregoing discussion and illustrations have been informative and feel that the following points may be made in conclusion:

1. Cost is a vitally important criterion in decisionmaking.

2. The cost analyst can provide meaningful insights into the effect upon costs of changes in the design or operation of a proposed system.

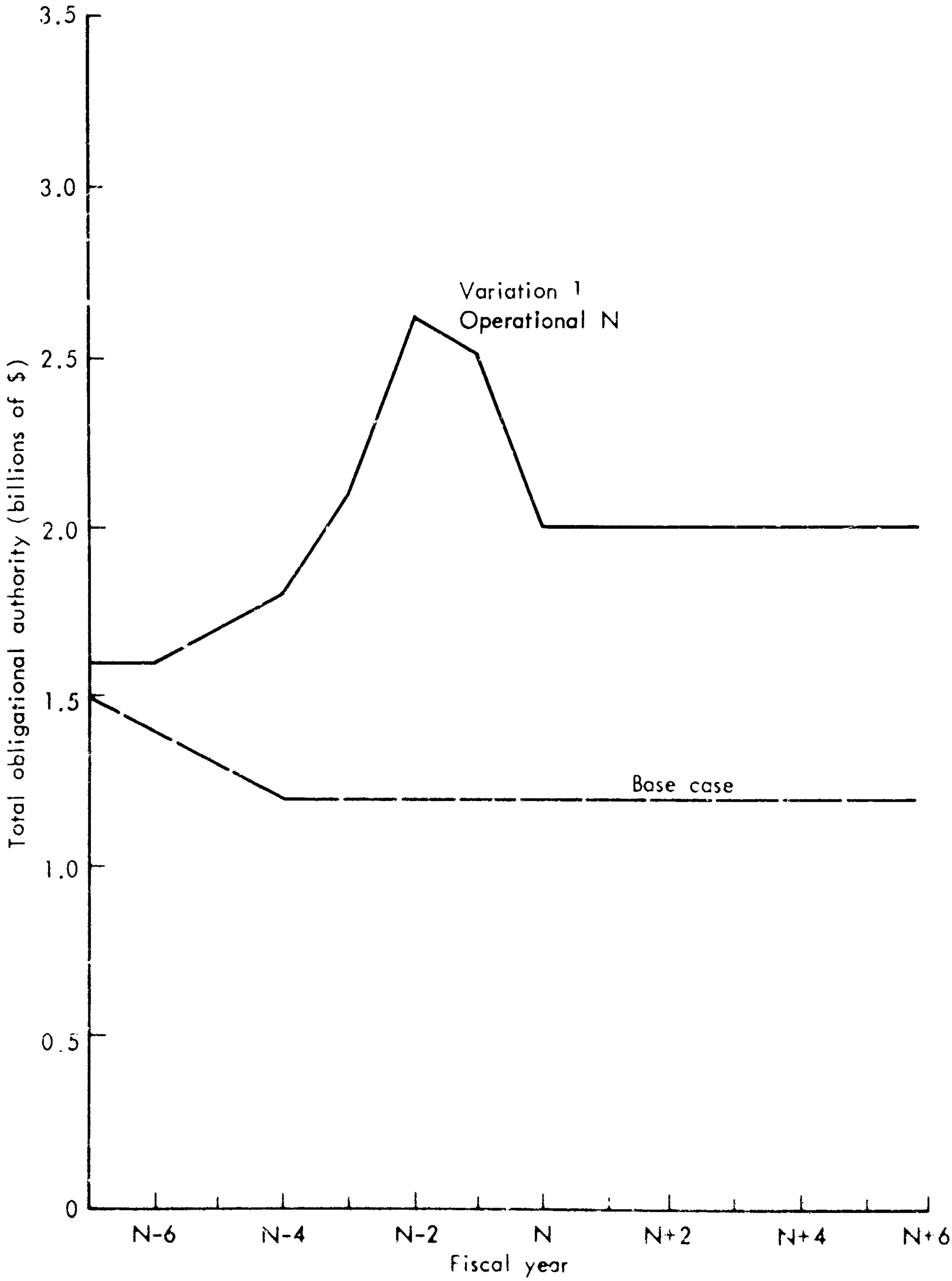

Fig. 11—Total obligational authority by fiscal year

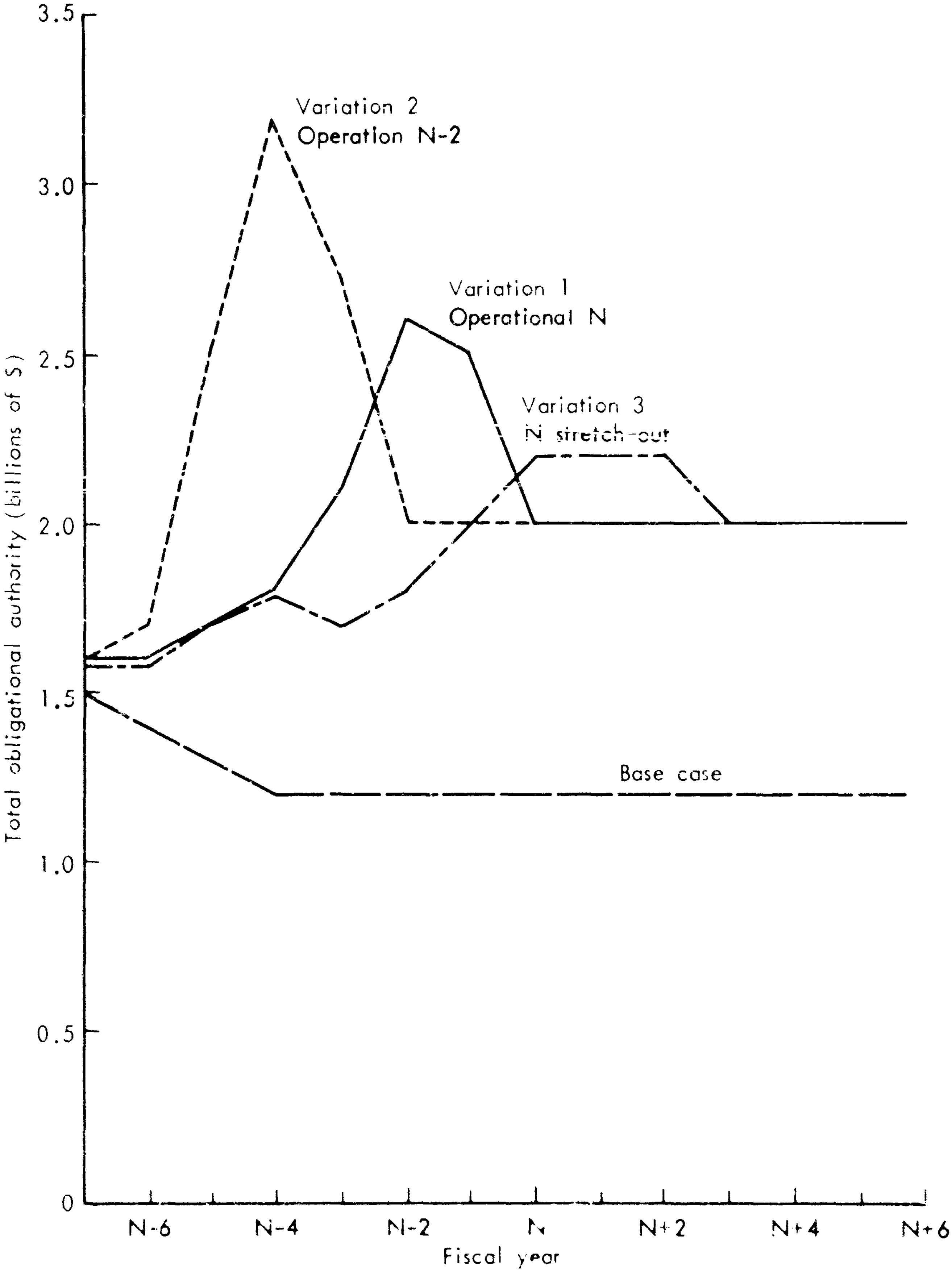

Fig 12—Total obligational authority by fiscal year

3. The cost analyst, given the opportunity, can point out areas for further study which promise high payoff in terms of weapon system cost reduction.

4. To do this job, the cost analyst must be brought into the study at the beginning, <u>before</u> the major design and operational decisions have been made.

In short, we might say that the proper role of the cost analyst is to play the cost-effectiveness game and not be just the scorekeeper.